ONTARIO MINISTRY OF ENVIRONMENT
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Ontario's Air Pollution Index

Ontario

Ministry of the Environment

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ONTARIO'S AIR POLLUTION INDEX

Air pollution being such a topical subject today, it is desirable for the public to have a day-to-day knowledge of pollution levels and be readily able to compare these levels with those reached during "air pollution episodes". It is well known that such episodes in the past, in other parts of the world, have caused an increase in human sickness and mortality for people with respiratory problems. In Ontario the day-to-day levels are obtained by using an Air Pollution Index, developed by the Air Management Branch as a basis for action in an alert system to control or prevent an air pollution episode.

Epidemiological studies indicate a relationship between the severity of health effects and the degree of air pollution measured by concentrations of particulate matter and sulphur dioxide.

Although extensive data was available for analyses of the concentrations of these pollutants during episodes, there was little information on the concentration of other pollutants. While it would seem desirable to have the Index as a function of concentrations of all pollutants possibly involved, the small amount of data available on other pollutants to use as weighting in an equation made it necessary, for the present time, only to consider sulphur dioxide and particulate matter.

Several other areas have developed air pollution indices, many of them designed for particular pollutants. For example, the Department of Health of Detroit devised an index based only on the coefficient of haze. The index, known as "MURC" (Measure of

Undersirable Respirable Contaminants = 70 x $(COH)^{.7}$) is also used in Buffalo, New York.

An air pollution index used in the Bay Area, San Francisco, is based on oxidants, nitrogen dioxide, carbon monoxide and particulate matter, the latter expressed as the coefficient of haze.

The index, known as the Combined Pollutant Index,[2] has the formula $CPI = 2(OX)+(NO_2)+(CO)+10(COH)$ where oxidants and nitrogen oxides are concentrations in p.p.h.m. and carbon monoxide in p.p.m. The weighting given to the constituents, oxidants (200), carbon monoxide (1), nitrogen dioxide (100) and coefficient of haze (10), indicates an emphasis on photochemical smog.

M.M. Braverman and C. Thephil[3] devised an index for New York City based on sulphur dioxide, carbon monoxide and the coefficient of haze. An index designed by M.H. Green[4] based on sulphur dioxide and coefficient of haze has been used for air pollution potential forecasting for Sarnia, Ontario. By defining desirable and extreme levels of SO_2 and COH, Green determined an index for each as follows:

$$SO_2 \text{ index} = 84(SO_2)^{0.431}$$

$$COH \text{ index} = 26.6\ (COH)^{0.576}$$

where

SO_2 = concentration of SO_2 in p.p.m.

COH = coefficient of haze

$$\text{Green's API} = \frac{SO_2 \text{ index} + COH \text{ index}}{2}$$

The index for each contaminant is given equal weighting in determining the combined index. Other air pollution indices have been proposed by L.A. Clarenburg,[5] J.F. Clark and R.B. Faoro,[6] J.C. Fensterstock[7] et al, and T.A. Rich.[8]

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Ontario's Index

For reasons mentioned earlier, the concentrations of only sulphur dioxide and particulate matter were chosen to be the basis for Ontario's Index. Photochemically produced smog, comprising irritating oxidants resulting from the reaction of nitrogen oxides and hydrocarbons, does not occur frequently and thus in most Ontario cities is not as important as the reducing type smog comprised mainly of sulphur dioxide and particulate matter. In fact, both sulphur dioxide and particulate matter have been measured for some time in the industrial cities of the province, and emission surveys have determined the principal sources of these pollutants.

Legislation in Ontario authorizes the Minister of the Environment to order any source not essential to public health or safety to curtail or shut down its operations when pollution levels are reached that could be injurious to health. To make possible the use of the Index as one of the bases of such control, it was designed to relate to pollution levels which could cause severe health effects like those during air pollution episodes.

The other basis of control is a meteorological forecast indicating the potential persistence of high pollution conditions.

Sulphur Dioxide and Particulate Matter

To determine whether sulphur dioxide measurements could be used to indicate particulate matter, an attempt was made to correlate readings of SO_2 and COH readings. The correlation coefficient between the measured values was found to be quite low, especially during winter months when air pollution is an important factor in the development of an episode. Following are the correlation coefficients for each month:

$r_{Nov} = 0.29$; $r_{Dec} = 0.14$;
$r_{Jan} = 0.06$; $r_{Feb} = 0.31$

A similar, poor relationship was obtained for daily average

sulphur dioxide concentrations and high-volume sampler measurements. The low correlation indicated that sulphur dioxide cannot be used to indicate particulate matter, and the Index must be a function of both sulphur dioxide and particulate matter concentrations.

Sulphur dioxide is measured directly by continuous analyzers and there is no difficulty in telemetering the levels of this pollutant from remote field stations to the Air Management head office.

The suspended particulate matter, however, presents a problem. At present there is no method of measuring the concentrations of this pollutant directly for the periods of time desired and telemetering the measurements so that they are known on a real time basis.

At present, the techniques in Ontario involve the use of the Hemeon paper tape sampler and the high-volume sampler. The latter method provides concentrations in the desired units, $\mu g/m.^3$ The sampler draws a large volume of air (60 cubic feet per minute) through a filter paper for 24 hours. Measurements are obtained by weighing the filters in a laboratory before and after exposure. The data cannot be telemetered on a real time basis.

The Hemeon paper tape sampler can be set to provide hourly readings which can be telemetered. Air is drawn through a portion of a filter paper tape. The tape is automatically advanced to a new position after each sampling period. The fundamental basis of evaluating the sample is optical. The transmittance of light through both filter and deposit is compared with the transmittance through a clean portion of the filter.

The difference in transmittance is converted into units of "coefficient of haze" (COH) per thousand linear feet of air passing through the filter. A COH unit is defined as that quantity of light scattering solids on the filter which produces an optical density equivalent to .01 when measured by light transmission.

It is obvious that the COH measurements will not only depend on the amount of particulates in the air deposited on the tape, but also on the size, shape and opacity of the particulates. Each location will thus have a different relationship between the COH value measured and the true concentration of the particulates.

With measurements of COH representing particulate concentrations in the equation, the Index will differ for each community. However, by the method of design, the significance of Index levels will be the same. With respect to the size of the particles obtained by the tape sampler, Dr. W. J. Ingram[9] determined a high correlation with COH values and the number of particles in the size range affecting the respiratory systems.

The Design of an Index for Toronto

The relationship between the high-volume sampler data and COH values was determined for Toronto, as graphed in Figure 1. For comparison purposes, the relationship as determined for a New York station by Dr. Ingram is also shown.

For Toronto:

$\text{HI VO} = 240(\text{COH})^{.91}$ where HI VO = suspended particulate matter concentrations in $\mu g/m^3$

COH = coefficient of haze/1,000 linear feet of air

The correlation coefficient for the above relationship is .70.

Data for sulphur dioxide and suspended particulate matter during air pollution episodes was obtained from summaries of epidemiological studies given in references # 10, #11, # 12 and #13. The data plotted in Figure 2 indicates the variability of episode. An analysis of the data revealed the following pairs of values could be used as the threshold to a severe episode at which the Air Pollution Index is set to equal 100:

1. Suspended particulates 600 $\mu g/m^3$ which for Toronto

is equivalent to 2.74 COH and sulphur dioxide .13 p.p.m.

2. Suspended particulates 500 $\mu g/m^3$ equivalent to 2.24 COH and sulphur dioxide .25 p.p.m.

Setting the equation for the Air Pollution Index as a function of the 24-hour average concentrations of SO_2 and COH as follows:

$$API = A(COH) + B(SO_2) \qquad (2)$$

The weighting to be given for each pollutant may be determined by setting API at the threshold level of an episode equal to 100 and substituting the foregoing given pairs of values for the 24-hour average concentrations of COH and SO_2. Equation (2) can be solved for A and B becoming:

$$API' = 30.5(COH + 126.0(SO_2) \qquad (3)$$

For a desirable scale the API was made to be an exponential function of API', that is, $API = C[API']^D$

$$API = C[30.5(COH) + 126.0(SO_2)]^D \qquad (4)$$

The levels of coefficient of haze and sulphur dioxide set by Ontario Regulations as objectives are 24-hour averages of COH at 1.0 and SO_2 at .10 p.p.m. Setting API = 32 at these levels provides a range of indices twice as great, that is, from 33 to 100, for control action to take place than for the range of acceptable levels, 0 to 32. Substituting API = 100 for levels of COH and SO_2 given above and API = 32 when COH = 1.0 and SO_2 = .10 equation (4) can be solved for C and D to give the equation for the Air Pollution Index for Toronto as follows:

$$API = .2[30.5(COH) + 126.0(SO_2)]^{1.35}$$

Figure 2 shows the boundaries for API equal to 100 and 32 as well as for 50 and 75. Figure 3 illustrates the levels of the Index and describes effects of the pollution during a number of episodes. High pollution levels persisted during these episodes for more than one day. Setting the Index at 100 based on 24-hour averages, provides a margin of safety for action to take place before the severe effects of air pollution can take place.

The report by L. J. Brasser et al[12] noted that the number of days on which pollution levels remained high had a very marked effect on the severity of the episode. Temperatures were also a factor affecting the daily mortality increases. Most of the severe episodes with increased mortality occurred during the winter. For this reason, the relationship between high-volume samples and COH data was based on winter data only (November to March).

An Air Pollution Alert System

An Air Pollution Index of less than 32 is considered acceptable. At these levels concentrations of sulphur dioxide and particulate matter should have little or no effect on human health. At the Advisory Level at which the Air Pollution Index = 32, and meteorological conditions are expected to remain adverse for at least six more hours, owners of significant sources of pollution in the community in which this Index occurs may be advised to prepare to curtail operations.

The "First Alert" occurs when the Air Pollution Index reaches 50 and meteorological forecasts indicate high pollution potential conditions for at least six more hours. Owners of major sources may be ordered to curtail operations.

P. J. Lawther[14] reported that patients with chronic respiratory disease may experience accentuation of the symptoms during SO_2 levels of .21 p.p.m. and particulate levels of 300 $\mu g/m^3$ corresponding to 1.3 COH. At this level the Air Pollution Index is equal to 58. This evidence as well as studies by B. W. Carnow et al[15] formed a basis for the proposed "First Alert" at 50, which incorporates a safety factor.

If the abatement action does not succeed to lower the levels of the Index, the "Second Alert" will be issued when the Index of 75 is reached and high pollution potential conditions are forecast for at least six more hours. Furthur curtailment of operations of

sources producing emissions of pollution will be ordered.

At the "Air Pollution Episode Threshold Level" at which the Index reaches 100 and is forecast to continue for at least six more hours, owners of all sources not essential to public health or safety will be ordered to cease operations. At this level the conditions could have mild effects on healthy people and seriously endanger those with severe cardiac or respiratory disease.

The Index went into effect in Toronto on March 23, 1970 and was gradually expanded to other cities in the province. It went into operation in Hamilton on June 15, 1970; Sudbury on January 15, 1971; Windsor on March 19, 1971.

Grey Cup Smog 1962

In retrospect the highest Air Pollution Index occurred in Toronto during November 30 to December 4, 1962, with the level reaching a peak reading of 155 during the evening of December 1, 1962 and 125 during the early morning hours of December 4, 1962.
(See Figure 5).

Very light winds with temperatures ranging from 34 to 50 degrees and relative humidity of 10 per cent prevailed throughout most of the period.

However there is no recorded medical evidence of an increase in hospital admissions of people with respiratory illness during this period.

This evidence indicates that the planned action authorized at an Index of 100 provides a safety factor with regard to the prevention of a serious air pollution incident.

Summary

The Air Pollution Index has been designed for use as the basis of an Air Pollution Alert System. Where the Index has been in operation, owners of pollution sources have co-operated in decreasing their emissions when advised that levels of the Index were near or approaching the 32 level. These actions have helped maintain lower levels of pollution. In all areas, permanent, pollution abatement programs are in progress which should prevent future high Index levels.

The Index equation differs from place to place according to the relationship between particulate matter concentration, expressed in weight per unit volume of air, and the measure of coefficient of haze. The design method followed, however, ensures that Index values have the same significance for each community.

The equation for the Index could be readily modified to relate directly to concentrations of suspended particulate matter, should an instrument become available capable of directly measuring and telemetering particulate concentrations on a continuous basis in the size range desired.

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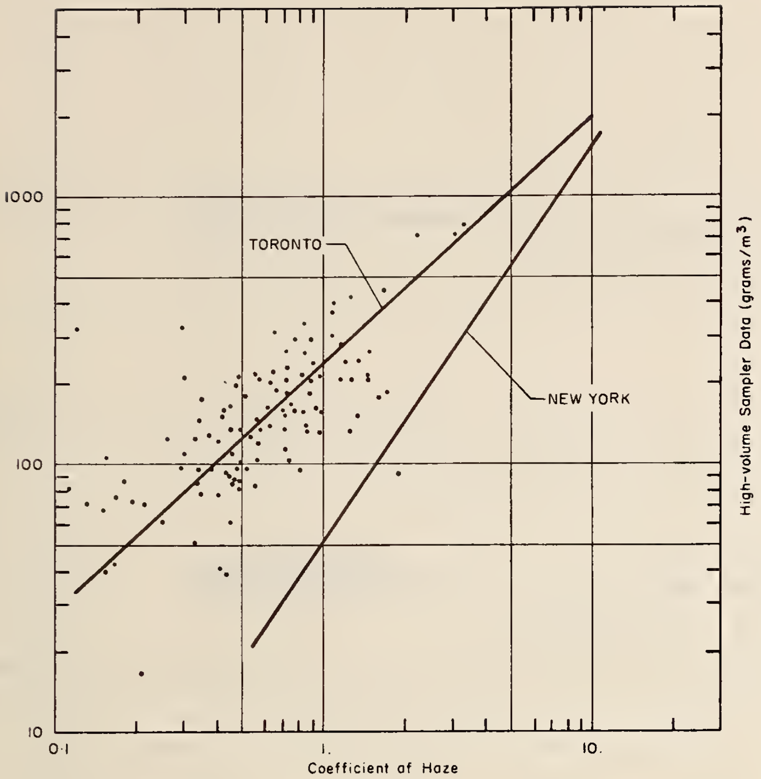

FIGURE 1: Relationship between the coefficient of Haze and high-volume sampler data for Toronto and New York

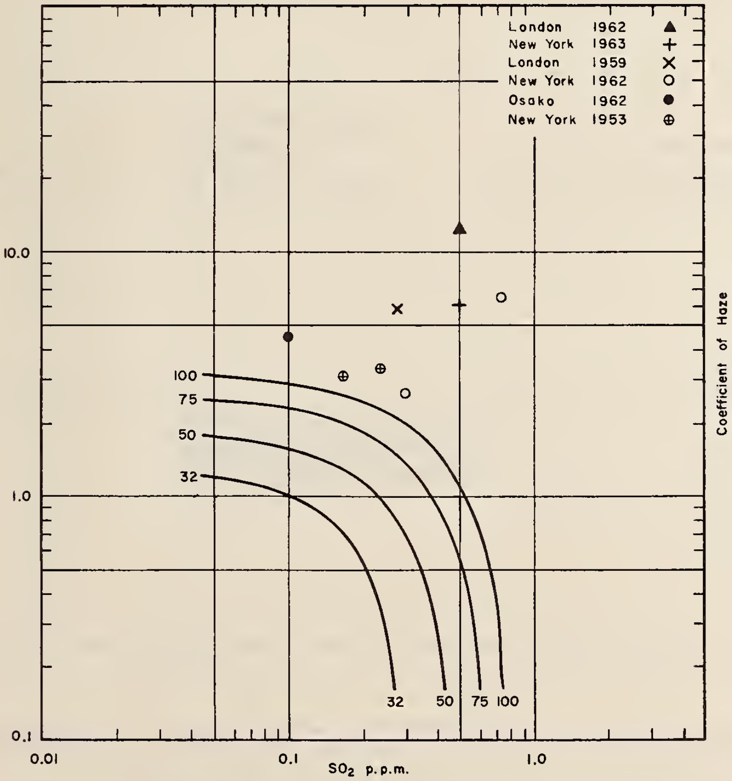

FIGURE 2: Air Pollution Index boundaries for values of 32, 50, 75 and 100 with episode levels plotted.

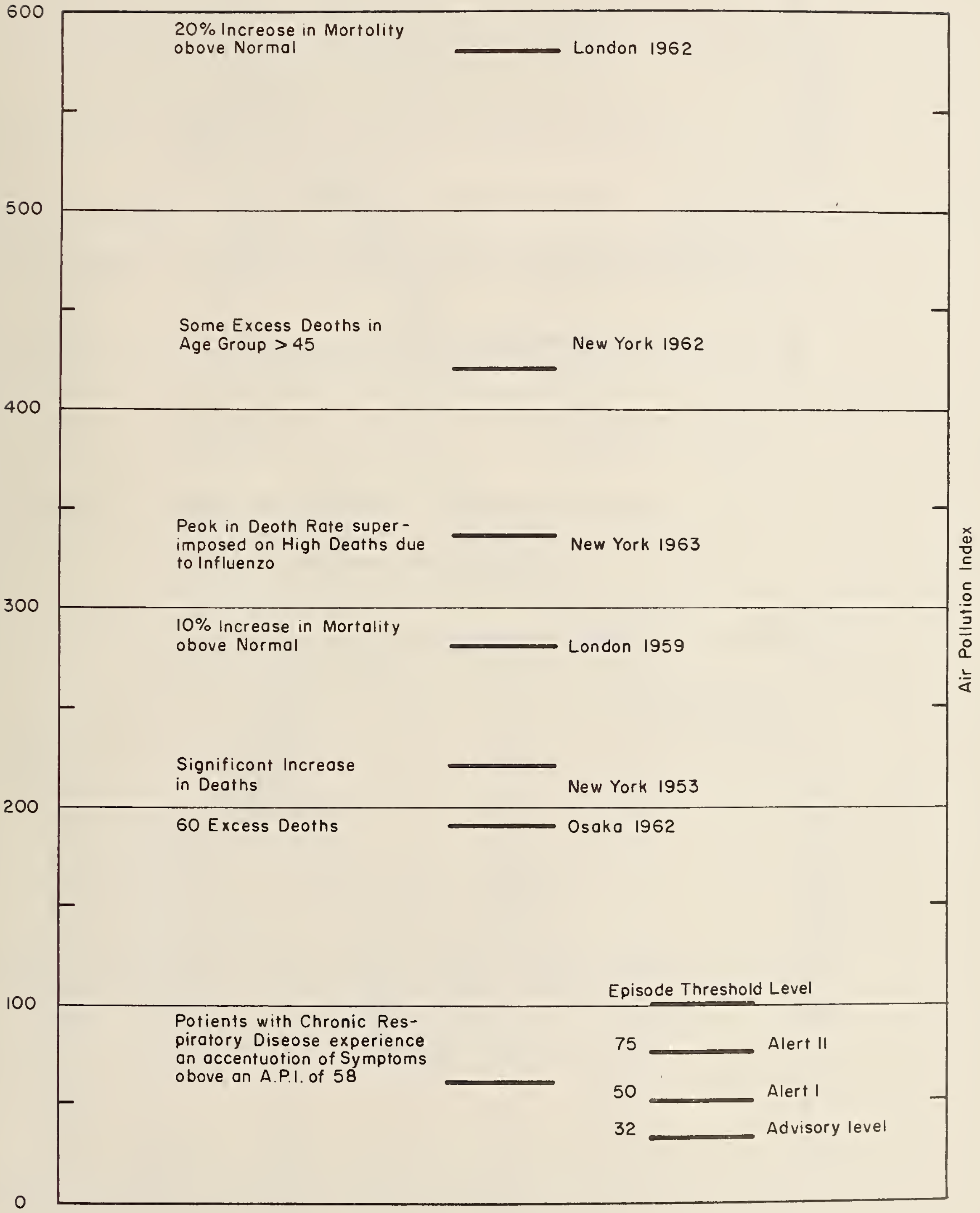

FIGURE 3: Levels of the Air Pollution Index during episodes and Ontario Alert System.

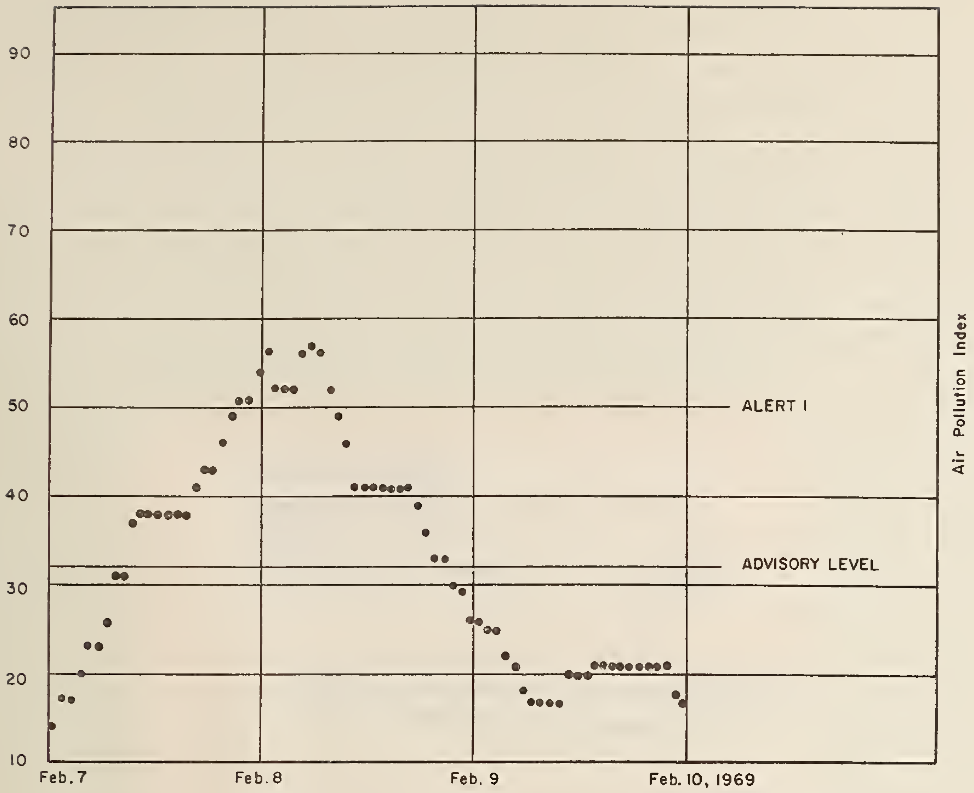

FIGURE 4: Index for period of highest pollution levels in Toronto during 1969.

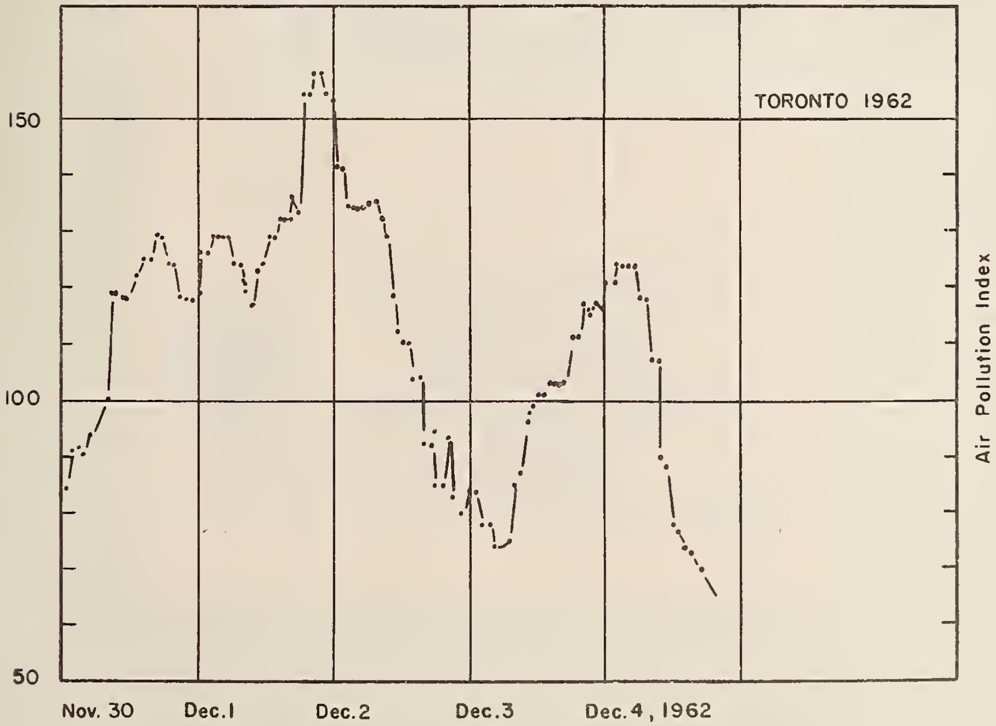

FIGURE 5: Air Pollution Index for period of highest pollution levels in Toronto.

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